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EXPLORATION OF UNDERUTILIZED LEAFY VEGETABLE BASELLA (*BASELLA ALBA* L.) FOR B-CAROTENE ENHANCED KHAKHRA

Amulya S.P.[1*], Bhuvaneshwari G.[2], Laxman Kuknoor[3], Vasant M. Ganiger[4] and DeepaTerdal[5]
[1]Department of Postharvest Management, College of Horticulture, Bagalkot, University of Horticultural Science, Bagalkot - 587104, Karnataka, India
[2]Department of Food Science and Nutrition, College of Horticulture, Bagalkot- 587104, Karnataka, India.
[3]Department of Postharvest Management and Associate Director of Research Extension (Central Zone), RHREC (Kumbapur), Dharwad- 580020, Karnataka, India
[4]Department of Vegetable Science and Division Head, Farmers Training Centre, Office of the Directorate of Extension, University of Horticultural Science, Bagalkot - 587104, Karnataka, India.
[5] Department of Food Science and Nutrition, Directorate of Extension, University of Horticultural Science, Bagalkot - 587104, Karnataka, India.
*Corresponding author E-mail: amulyasp200102018@gmail.com
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ABSTRACT

The present study was undertaken to determine the sensory quality and nutrient content of *khakhra* prepared with the incorporation of dehydrated Basella leaf powder (BLP) at 5, 7.5, 10, 12.5 and 15 per cent level. *Khakhra* were prepared by using wheat flour as base ingredient along with BLP. The developed *khakhra* were sensorily evaluated using nine-point hedonic scale. *Khakhra* prepared with 7.5 per cent of dehydrated BLP was best acceptable and used for their nutrient computation. Results revealed that *khakhra* prepared with (7.5 %) BLP was found to be high in moisture (6.53 %), water activity (0.31 aw), crude protein (15.40 %), crude fiber (3.10 %), ash (5.74 %), calcium (74.12 mg), magnesium (115.90 mg), iron (6.20 mg), potassium (501mg), zinc (2.60 mg), β-carotene (340.33 µg/100 g), total polyphenol (110.10 mg GAE/100 g), higher antioxidant activity (33.02 mg AAE/100 g) and with lowest crude fat (3.40 %), total carbohydrate (65.83 %) and calorific value (355.52 kcal/100 g). The storage life study based on sensory evaluation, microbial load, peroxide value and moisture content revealed that *khakhra*s were acceptable up to 3 months in aluminium pouches under ambient condition.

***Keywords*:** Basella, *Khakhra*, nutrient composition, β-carotene, antioxidant activity.

Introduction

Basella (*Basella alba*) belongs to the Basellaceae family with indigenous to tropical southern Asia and most likely originated in Indonesia or India Vanaliya *et al.* (2012). It a versatile green leafy vegetable, holds significant potential in addressing Vitamin A deficiency (VAD), a major global health issue affecting millions, especially in low- and middle-income countries. VAD is a leading cause of preventable childhood blindness and increases vulnerability to infections and mortality. *Basella alba* is rich in β-carotene, a provitamin A carotenoid crucial for converting into vitamin A in the body. This crop could play a vital role in combating "hidden hunger," which includes deficiencies in essential nutrients like iodine, iron and zinc (Khalid *et al*., 2020).

Nutritionally, Basella is an excellent source of vitamins A, B, C, calcium and iron, with only 19 kcal per 100 g of uncooked leaves (Glassgen *et al*., 1993). Its high content of carotenoid antioxidants, including β-carotene, offers numerous health benefits, such as anti-inflammatory, antioxidant and antibacterial

properties (Shade *et al.,* 2017). The mucilage in *Basella* also promotes digestive health by aiding smooth digestion and reducing cholesterol absorption.

Basella alba offers a sustainable, food-based approach to combating micronutrient deficiencies. By incorporating Basella leaf powder into various food products, it can help to improve β-carotene intake, thereby addressing VAD and other health issues linked to nutrient deficiencies. The development of β-carotene-enhanced products, nutrient analysis and studies on storage stability are essential for maximizing its potential as a biofortified crop. This would provide an affordable, culturally appropriate and scalable solution to improving public health, particularly in communities facing micro nutrient deficiency.

Materials and Methods

Procurement of raw material

The *Basella alba* was planted in the University of Horticultural Sciences, Bagalkot. After 45 days of planting, healthy leaves were harvested from the stem and used in the experiment. The groceries required for the preparation of *khakhra,* i.e., wheat flour, Bengal gram flour, bajra flour, cumin seeds, chilli powder, turmeric powder, salt and oil were purchased from the local market in Vidyagiri, Bagalkot.

Preparation of BLP

The harvested Basella (*Basella alba*) leaves were washed with water and spread under fan to remove the surface moisture and dried in a cabinet tray dryer at 55 °C. The dried leaves were then powdered using a grinder and sieved to obtain a fine powder, then stored in an airtight aluminum pouch. This dried BLP was analyzed for proximate composition, water activity, colour value (*L*, a*, b**), antioxidant activity, total polyphenols, β-carotene content and used for further preparation of value-added products.

Formulation of *khakhra*

Five treatments of *khakhra* containing varying proportions of BLP at 5, 7.5, 10, 12.5 and 15 grams along with other ingredients to select the acceptable ratio (Table 1) was carried out. The standard procedure was applied for preparation of *Khakhra* as mentioned by Akshata (2018). The experiment was carried out with four replications. Prepared *khakhra* was packed in aluminum pouches and stored at ambient temperature for further storage studies.

Sensory evaluation of *khakhra*

Sensory evaluation of developed *khakhra* was evaluated by panel of semi-trained individuals, including teachers and postgraduate students from the College of Horticulture, Bagalkot using nine-point hedonic scale. Scores were given based on the appearance/color, flavor, texture/consistency, taste and overall acceptability as per Begum *et al*. (2018).

Physical characteristics of *khakhra*

Physical quality attributes of *khakhra* such as yield (%), instrumental texture (N) was determined using a TA-XT-Plus Texture Analyzer (Stable Micro Systems, Model: Texture Export Version 1.22) by following the approach of Park and Baik (2004) and Instrumental color values (*L**, *a** and *b** values) of dehydrated BLP as well as *khakhra* were determined using a Digital Hunter Colorimeter D25 optical sensor (Chouhan *et al*., 2019).

Nutritional composition of Basella leaves incorporated *khakhra*

Nutritional composition analysis was carried out on the sensorily best-accepted treatment among the formulated *khakhra*, along with a control *khakhra* with three replications.

Proximate composition: Nutritional composition of dehydrated BLP as well as *khakhra* was analyzed as per standard procedure. The proximate composition such as moisture was measured using a Radwag moisture analyzer (Model: MAC 50, Make Poland), crude protein by using Micro Kjeldahl method, crude fat by using automatic Soxhlet apparatus (Model: SOCS PLUS; Pelican Equipments, Chennai) by following the method of Ojure and Quadri (2012), crude fiber performed using the Fibra Plus-FES-6 instrument, ash by using a muffle furnace, carbohydrates were estimated as per AOAC (1980),Calorific value was determined by differential method (BeMiller, 2017), water activity by using a water activity meter (Labswift-aw, Novasina) as describe by Abbey and Ibeh (1998).

Minerals: Mineral's content of *khakhra* such as calcium and magnesium content were measured using the complexometric titration method as described by Jackson (1973), the iron and zinc were determined according to Lindsay and Norvell, (1978) by atomic absorption spectrophotometer and the potassium concentration was determined by using a flame photometer as per AOAC (1980).

Functional parameters: Functional parameters of dehydrated BLP as well as *khakhra*s uch as β –carotene was estimated by colorimetric method as outlined by (Ranganna, 2002), while total phenols were determined by Folin Ciocalteu assay as gallic acid equivalent in mg GAE/100 g and antioxidants were determined by FRAP method as outlined by Benzie and Szeto (1999).

Storage studies of Basella leaves incorporated *khakhra*

Storage life research was carried out on the best-accepted treatment among the formulated *khakhra*, along with a control *khakhra* with three replications. The products were packaged in aluminum pouches and stored under ambient condition for 3 months were assessed at 15 days intervals for its moisture, water activity, Sensory evaluation, instrumental color values and peroxide value as per Bligh and Dyer (1959) method. The total microbial count analysis of *khakhra* was carried out using serial dilution and spread plate method according to Ranganna (1986).

Statistical analysis

The physical characteristics and sensory evaluation data from experiments were analyzed using a completely randomized block (CRD) design, as described by Panse and Sukhatme (1985). Nutritional composition and storage studies of products was analyzed using two sample 't' test. The significance level for the 'F' and two sample 't' tests was set at p = 0.01. Critical difference values were determined whenever the 'F' and 't' test showed significance at this level.

Results and Discussion

Nutritional composition and functional parameters of dehydrated Basella powder

The physico-chemical parameters of dehydrated Basella powder were recorded with three replication and are presented in the Table 2. The mean values observed were as follows: moisture content (12.6 %), water activity (0.27), crude protein (18.94%), crude fat (0.40%), crude fibre (13.00%), ash content (15.42%), total carbohydrates (39.64 %) and colour values *L** (48.64), *a** (-1.78) and *b** (28.34). Additionally, the powder had an antioxidant activity of 2.20 mg AAE/100 g, total phenols of 4.76 mg GAE/100 g and a β-carotene content of 2100 µg/100 g.

Physical characteristics of *khakhra*

Yield (%): The percentage yield of *khakhra* influenced by varying concentrations of BLP is shown in Table 3. The highest yield (87.92 %) was recorded in T6 (45 g WF + 15 g BLP), followed closely by T5 (47.5 g WF + 12.5 g BLP, 87.06%). The lowest yield (83.06%) was in T_1 (60 g WF). The increased yield is attributed to the high dietary fiber content of BLP, which enhances water absorption and subsequently improves yield. Similar findings were reported by Sudha *et al*. (2007) for apple pomace powder in cakes and Ajila *et al*. (2008) for cereal bran and mango peel powder in biscuits.

Instrumental texture (N): The texture of *khakhra* increased significantly with the incorporation of BLP, ranging from 2.80 N to 4.59 N, as shown in Table 3. The highest texture was observed in T6 (45 g WF + 15 g BLP: 4.59 N), followed by T5 (47.5 g WF + 12.5 g BLP: 3.53 N). The lowest texture was recorded in T_1(60 g WF: 2.80 N). The increase in hardness is attributed to the fiber content of BLP, which enhances oil and water absorption. Similar results were found by Shobhit and Sharma (2023) and Maghu *et al*. (2017) with drumstick leaf incorporation.

Instrumental colour value (*L, *a**, *b**):** The color values (*L**, *a**, *b**) of *khakhra* decreased as the concentration of BLP (BLP) increased, as shown in Table 3. The highest *L** (29.88), *a** (7.26) and *b** (28.85) were observed in T_1(60 g WF), while the lowest values were recorded in T6 (45 g WF + 15 g BLP) with *L** (20.22), *a** (2.07) and*b** (20.46). This reduction is due to Basella's chlorophyll, which increases greenness, reduces lightness, and masks the yellow pigments. Similar trends were reported in moringa-fortified *khakhra* by Shobhit and Sharma (2023).

Sensory evaluation of *khakhra*

The sensory evaluation of Basella incorporated *khakhra* with different levels of BLP incorporation (Table 4). The highest scores were recorded in T_3 (52.5 g WF + 7.5 g BLP) for flavor (8.75), texture (8.5), taste (8.75) and overall acceptability (8.75), while T_1(60 g WF) achieved the highest score of 8.5 for color. Conversely, T_1 (60 g WF) had the lowest scores for flavor, texture, tasteand overall acceptability (all 8.00) and T_4 (50.0 g WF + 10.0 g BLP), T_5 (47.5 g WF + 12.5 g BLP) and T_6 (45 g WF + 15 g BLP) had the lowest scores for color (7.5). The study found that *Khakhra* with (7.5 %) *Basella alba* powder was most preferred by panelists, likely due to the mild flavor and aroma of Basella leaves. Based on sensory evaluation, treatment T_3 (52.5 g WF + 7.5 g BLP) scored highest overall acceptability score and it was taken for further nutritional and storage studies along with control (T_1: 60 g WF).

Nutritional composition of *khakhra*

Moisture (%): Treatment T_3 (52.5 g WF+ 7.5 g BLP) had the highest moisture content (6.53%), while T_1(60 g WF) had the lowest (6.25%). The higher moisture in T_3 is due to the water-holding capacity of Basella's crude fiber and mucilaginous substances. Similar findings were reported by Shobhit and Sharma (2023) with moringa powder and Akshata (2018) with betel leaf powder.

Water activity: Though non-significant, water activity was highest in T_3(0.31) and lowest in T_1 (0.30), correlating with increased moisture from Basella leaf powder incorporation, as noted by Hamsa *et al*. (2021) with spine gourd powder.

Crude protein (%): The treatment T_3 (52.5 g WF + 7.5 g BLP *Khakhra*: 15.40 %) had a substantially higher crude protein content than the T_1 (60.0 g WF *khakhra*: 15.10) this was due to the greater crude protein levels in Basella. The amount of crude protein in the *Khakhra* increased as a result of the addition of 7.5 per cent BLP. Studies by Kajla *et al*. (2020) and Shobhit and Sharma (2023) revealed a similar tendency.

Crude fat (%): Significantly higher crude fat (3.70 %) was observed in T_1 (60.0 g WF *khakhra*), due to addition of 7.5 per cent of BLP and lowest (3.40 %) was observed in T_3(52.5 g WF + 7.5 g BLP *Khakhra*). Because of less crude fat content present in Basella compared to WF. Hamsa *et al*. (2021) confirmed the decrease in crude fat content with increased incorporation of spine gourd powder in *khakhra* and *ribbon.*

Ash (%): According to the data, T_3 had the greatest ash content (52.5 g WF + 7.5 g BLP *Khakhra*: 5.74 %) and T_1 had the lowest ash level (60.0 g WF *khakhra*: 4.41 %). The addition of mineral-rich BLP is responsible for the rise in ash concentration. These results are in line with those of Akshata (2018), who also observed that replacing WF with betel leaf powder increased the amount of ash.

Crude fibre (%): In this investigation, adding BLP to the *Khakhra* boosted its crude fibre content. Treatment T_3 had the highest crude fibre content (52.5 g WF + 7.5 g BLP *Khakhra*: 3.10 %), whereas, T_1 had the lowest crude fibre content (60.0 g WF *khakhra*: 2.80 %). This rise can be attributed to *Basella alba* flour's greater crude fibre content than WF. These findings agree with those of Kajla *et al*. (2020), who observed that adding curry leaf powder enhanced the amount of crude fibre in *Khakhra*. Akshata (2018) noticed a similar pattern when betel leaf powder was used in place of WF.

Total carbohydrates (%): Treatment T_1 (60.0 g WF *khakhra*; 73.99 %) had the highest carbohydrate content in the current study, whereas T_3 (52.5 g WF + 7.5 g BLP *Khakhra*; 65.83 %) had the lowest carbohydrate content. Because BLP had less crude fat and more moisture, ash, crude protein and crude fibre due to this reason the amount of carbohydrates in T_3 was significantly reduced. Similar patterns were noted by Kajla *et al*. (2020) in *Khakhra* with rising curry leaf powder levels and by Akshata (2018) in *Khakhra* with the addition of betel leaf powder.

Calorific value: Treatment T_1 (60.0 g WF *khakhra*: 389.66 kcal/100 g) had the considerably highest calorific value, whereas T_3 (52.5 g WF + 7.5 g BLP *Khakhra*: 355.52 kcal/100 g) had the lowest. In the present study, when BLP was added the amount of carbohydrate invariably decreases; thereby the overall calorific value was also reduced. These findings are in agreement with the studies reported by Akshata (2018), who found that *Khakhra* made with betel leaf powder had a lower energy value compared to its control.

Total polyphenol: The highest total polyphenols were recorded in T_3 (52.5 g WF + 7.5 g BLP *Khakhra:* 110.10 mg GAE/100 g) and lowest polyphenols were seen in T_1 (60.0 g WF *khakhra*: 67.00 mg GAE/100 g) which is due to the higher phenolic content in *Basella alba* which was (4.76 mg GAE/100 g), observed in the present study. These findings are consistent with those reported by Shobhit and Sharma (2023).

β-carotene: Treatment T_3 (52.5 g WF + 7.5 g BLP *Khakhra*) had the considerably highest levels (340.33 µg/100 g) and the lowest amount of β-carotene was obtained in T_1 (60.0 g WF *khakhra*: 49.67 µg/100 g). Because of the high quantities of β-carotene in *Basella alba.* β-carotene in BLP (7.5 g) incorporated *Khakhra*was 6.85 folds higher than the control *Khakhra*. These findings coincide with those of Akshata (2018), who also observed that adding betel leaf powder to *Khakhra* raised the amount of β-carotene content compared to control.

Antioxidants activity: T_3 had the highest recognized antioxidant capacity of 33.02 mg AAE/100 g (52.5 g WF + 7.5 g BLP *Khakhra*), whereas T_1 had the lowest antioxidant capacity of 20.06 mg AAE/100 g (60.0 g WF *khakhra*). The high concentration of total polyphenols and beta carotene content of *Basella alba* is responsible for the considerable increases in antioxidant activity in T_3 that occur with adding (7.5 %) BLP. According to Shobhit and Sharma's studies (2023), *khakhra* enhanced with powdered moringa leaf showed the similar pattern of rising antioxidant.

Minerals: The mineral composition recorded in study shows that the treatment T_3 (52.5 g WF + 7.5 g BLP *Khakhra*) had more calcium (74.12 mg), magnesium (115.9 mg), iron (6.20 mg), potassium (501.00 mg) and zinc (2.60 mg) than the T_1 (60.0 g WF *khakhra*: 58.14 mg, 112.00 mg, 5.90 mg, 488.00 mg and 2.29 mg, respectively). The increase in mineral content may be due to the rise in ash content of Basella leaf powder incorporated *khakhra*, as ash is an indicator of mineral content. Hamsa *et al*. (2021) reported a significant

increase in mineral content in *Khakhra* prepared with the addition of spine gourd powder. These findings are consistent with those of Akshata (2018), who observed a similar increase in mineral content in *Khakhra* enriched with betel leaf powder.

Storage studies of Basella leaves incorporated *khakhra*

Moisture (%): The moisture content of *khakhra* stored at room temperature in aluminum pouches increased over 90 days. T_1 (60 g WF) rose from 6.25 to 7.58 per cent, while T_3 (52.5 g WF + 7.5 g BLP) increased from 6.53 to 8.20 per cent. T_3 had significantly higher moisture, likely due to its sorption properties, relative humidity and storage conditions. Similar findings were noted by Akshata (2018) with betel leaf powder in *khakhra*. Reddy *et al*. (2005) and Sriwattana *et al.* (2008) also observed moisture increases in stored snacks, affecting texture and crispness.

Water activity (aw): The water activity values of *khakhra* ranged from 0.30 to 0.53, with minimal changes during the initial storage days at room temperature. Treatment T_3 (52.5 g WF + 7.5 g BLP) had the highest water activity throughout storage (0.34 to 0.53), while T_1 (60 g WF) had the lowest (0.32 to 0.46). Both treatments showed an increase in water activity over time, with T_3 exhibiting a greater percentage increase. This rise is attributed to moisture absorption from the surrounding environment during storage.

Peroxide values: The peroxide values of *khakhra* varied significantly between treatments after 30 days of storage, ranging from 0.40 to 3.30 meq/kg. T_3 (52.5 g WF + 7.5 g BLP) had the lowest peroxide values (0.40 to 2.20 meq/kg), while T_1 (control) had the highest (0.50 to 3.30 meq/kg) over the 3-month period. The lower peroxide values in T_3 are attributed to the antioxidant properties of BLP. Both treatments showed an upward trend in peroxide values due to oxidation, consistent with findings by Kamble *et al*. (2018) in drumstick noodles and Sharma (2010) in *Aloe vera* leaf powder-incorporated snacks.

Microbiological growth: In *khakhra*, no microbial growth was observed initially, but bacterial and mold development increased significantly after 90 days of storage, likely due to rising moisture content, which provided free water for microbial growth. Despite the increase, levels remained within safe consumption limits, likely due to the heat used during preparation. Treatment T_3 (52.5 g WF + 7.5 g BLP) had lower bacterial (0.74×10^3 cfu/g) and mold (0.80×10^2 cfu/g) counts compared to T_1 (control), which had higher bacterial (0.88×10^3 cfu/g) and mold (1.09×10^2 cfu/g) counts. The antibacterial properties of BLP likely contributed to the reduced microbial growth in T_3. These findings align with Akshata (2018), who reported that betel leaf's antibacterial properties significantly reduced microbial populations in betel leaf-incorporated *khakhra*.

Sensory evaluation: *Khakhra* samples were evaluated using a 9-point hedonic scale at 15-day intervals over a 3-month period, revealing a decline in sensory scores during storage (Fig. 10). In T_1 (control), scores decreased from 8.5 to 7.1 for color, 8.0 to 7.1 for taste, 8.0 to 6.92 for flavor, 8.0 to 7.42 for texture, and 8.0 to 7.0 for overall acceptability. T_3 (52.5 g WF + 7.5 g BLP) showed a milder decline: from 8.0 to 7.4 for appearance, 8.0 to 7.5 for taste, 8.75 to 7.67 for flavor, 8.5 to 8.12 for texture and 8.75 to 7.92 for overall acceptability. The reduction in scores was attributed to factors like light exposure, moisture absorption, lipid peroxidation, and non-enzymatic browning, which affected flavor and crispiness. Despite these changes, both *khakhra* treatments remained acceptable up to 90 days. These results are consistent with Akshata (2018), who reported similar declines in sensory quality alongside increase in moisture and microbial growth in *khakhra, papad* and *soup mixes*. Punia and Gupta (2009) also found declining sensory scores and increasing free fatty acids, peroxide values and sugars in stored products like soya ladoo and sev.

Instrumental colour value (*L*, a*, b):** Treatment T_1 *khakhra* (60.0 g WF) consistently exhibited higher instrumental color values (*L*, a*, b**) than T_3 (52.5 g WF + 7.5 g BLP) throughout the storage period. Initially, T_1 recorded *L** and *b** values of 29.88 and 28.85, which decreased to 27.10 and 27.34 by day 90, while its *a** value increased from 7.26 to 7.98. In contrast, T_3 began with *L** and *b** values of 22.07 and 23.43, which further declined and its a* value increased from 7.26 to 5.17 by day 90. The reduction in *L** and *b** values and the increase in *a** during storage were attributed to oxidative reactions, moisture absorption leading to non-enzymatic browning, and chlorophyll degradation. Similar observations were noted by Varsha (2023) in raw tamarind products and Kamble *et al*. (2018) in nutri-densed drumstick noodles.

Table 1: Treatment details of BLP incorporated *khakhra*

Treatments	T_1	T_2	T_3	T_4	T_5	T_6
Wheat flour (g)	60.00	55.00	52.50	50.00	47.50	45.00
Dehydrated Basella powder (g)	-	5.00	7.50	10.00	12.50	15.00
Bengal gram flour (g)	20.00	20.00	20.00	20.00	20.00	20.00
Bajra flour (g)	20.00	20.00	20.00	20.00	20.00	20.00
Cumin seeds (g)	1.00	1.00	1.00	1.00	1.00	1.00
Cumin powder (g)	1.00	1.00	1.00	1.00	1.00	1.00
Chilli powder (g)	2.00	2.00	2.00	2.00	2.00	2.00
Turmeric powder (g)	0.50	0.50	0.50	0.50	0.50	0.50
Edible salt (g)	2.00	2.00	2.00	2.00	2.00	2.00
Edible oil (ml)	10.00	10.00	10.00	10.00	10.00	10.00

WF- Wheat flour, BLP- Basella leaf powder

Table 2: Proximate composition, water activity, colour value (L*, a*, b*) and functional parameters of dehydrated *Basella alba* leaf powder

Parameters	Quantity (Per100g dry weight)
Moisture (%)	12.60 ± 0.01
Water activity	0.27 ± 0.02
*L**colour value	48.64 ± 0.10
*a**colour value	-1.78± 0.10
*b**colour value	28.34 ± 0.10
Ash (%)	15.42 ± 0.01
Protein (%)	18.94 ± 0.31
Crude fat (%)	0.72 ± 0.01
Crude fibre (%)	13.00 ± 0.06
Carbohydrates (%)	39.64 ± 0.10
Antioxidant activity	2.20 ± 0.20
Total phenols (mg GAE/100g)	4.76 ± 0.01
β-carotene (µg/100g)	2100 ± 0.02

Table 3: Effect of incorporation of Basella (*Basella alba*) leaf powder on yield, texture and color value of *Khakhra*

Treatment	Yield (%)	Instrumental texture (N)	Colour value		
			*L**	*a**	*b**
T_1: 60.0 g WF	83.06 ^{f}	2.80^{d}	29.88 ^{a}	7.26 ^{a}	28.85 ^{a}
T_2: 55.0 g WF+05 g BLP	84.45 ^{e}	3.23 ^{c}	24.32 ^{b}	5.56 ^{b}	26.32 ^{b}
T_3:52.5 g WF+7.5 g BLP	85.31 ^{d}	3.30 ^{bc}	22.07 ^{c}	4.46 ^{c}	23.43 ^{c}
T_4: 50.0 g WF+10.0 g BLP	86.15 ^{c}	3.40 b	21.16 ^{d}	3.54 ^{d}	22.73 ^{d}
T_5: 47.5 g WF+12.5 g BLP	87.06 ^{b}	3.53^{b}	20.25 ^{e}	2.43^{e}	21.67 ^{e}
T_6: 45.0 g WF+15.0 g BLP	87.92 ^{a}	4.59 ^{a}	20.22 ^{f}	2.07 ^{f}	20.46 ^{f}
Mean	**85.66**	**3.48**	**22.98**	**4.22**	**23.91**
S. Em ±	0.01	0.06	0.01	0.03	0.01
CD at 1%	0.05	0.27	0.04	0.11	0.05

Table 4: Effect of incorporation of Basella (*Basella alba*) leaf powder on sensory parameter (9-point hedonic scale) of *Khakhra*

Treatment	Colour	Flavour	Texture	Taste	Overall acceptability
T_1: 60.0 g WF	8.50 ^{a}	8.00 ^{c}	8.00 ^{b}	8.00 ^{c}	8.00 ^{c}
T_2: 55.0 g WF+05 g BLP	8.00 ^{b}	8.50 ^{b}	8.50 ^{a}	8.50 ^{b}	8.50 ^{b}
T_3:52.5 g WF+7.5 g BLP	8.00 ^{b}	8.75 ^{a}	8.50 ^{a}	8.75 ^{a}	8.75 ^{a}
T_4: 50.0 g WF+10.0 g BLP	7.50 ^{c}	8.50^{b}	8.50 ^{a}	8.50^{b}	8.50 ^{b}
T_5: 47.5 g WF+12.5 g BLP	7.50^{c}	8.50 ^{b}	8.50 ^{a}	8.50 ^{b}	8.50 ^{b}
T_6: 45.0 g WF+15.0 g BLP	7.50 ^{c}	8.00 ^{c}	8.50 ^{a}	8.00 ^{c}	8.50 ^{b}
Mean	**7.83**	**8.38**	**8.42**	**8.38**	**8.46**
S. Em ±	0.07	0.05	0.06	0.05	0.07
CD at 1%	0.31	0.23	0.25	0.23	0.29

Table 5: Proximate composition of Basella (*Basella alba*) leaf powder incorporated *Khakhra*

	T_1	T_3	t- value
Moisture (%)	6.25 ± 0.02	6.53 ± 0.01	24.25**
Water activity (aw)	0.30 ±0.01	0.31 ±0.01	NS
Crude protein (%)	15.10 ± 0.10	15.40 ± 0.10	3.67*
Crude fat (%)	3.70 ± 0.10	3.40 ± 0.10	3.67*
Ash (%)	4.41 ± 0.10	5.74 ± 0.05	15.83**
Crude fibre (%)	2.80 ± 0.10	3.10 ± 0.10	3.67*
Total carbohydrates (%)	73.99 ± 0.10	65.83 ± 0.10	99.94**
Calorific value (kcal/100 g)	389.66±0.10	355.52±0.10	418.13**

Table 6: Functional parameters and minerals composition (mg/100 g) of Basella (*Basella alba*) leaf powder incorporated *Khakhra*

	T_1	T_3	t- value
β-carotene (µg/100 g)	49.67 ± 0.57	340.33 ± 1.00	437.00**
Total phenols (mg GAE/100 g)	67.00 ± 1.00	110.10 ± 0.10	76.00**
Antioxidant activity (mg AAE/100 g)	20.06 ± 0.10	33.02 ± 0.10	158.73**
Calcium	58.14 ± 1.00	74.12 ± 1.00	195.71 **
Magnesium	112.00 ± 0.10	115.90 ± 0.10	6.72 **
Iron	5.90 ± 0.10	6.20 ± 0.10	3.67*
Potassium	488.00 ± 1.00	501.00 ± 1.00	15.92 **
Zinc	2.29 ± 0.10	2.60 ± 0.10	5.34*

Table 7: Moisture content, water activity and peroxide value of Basella leaf powder incorporated *Khakhra* during ambient storage condition

Products	Treatments	Initial	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Moisture (%)	T_1	6.25 ± 0.02	6.36 ± 0.01	6.54 ± 0.01	6.74 ± 0.01	7.05 ± 0.01	7.36 ± 0.01	7.58 ± 0.10
	T_3	6.53 ± 0.01	6.59 ± 0.01	6.83 ± 0.01	7.40 ± 0.01	7.46 ± 0.01	7.65 ± 0.01	82.0 ± 0.10
	t- value	**24.25****	**34.86****	**35.52****	**11.38****	**50.22****	**35.52****	**10.69****
Water activity (aw)	T_1	0.30 ± 0.01	0.32 ± 0.01	0.35 ± 0.01	0.40 ± 0.01	0.41 ± 0.01	0.44 ± 0.01	0.46 ± 0.01
	T_3	0.31 ± 0.01	0.34 ± 0.01	0.37 ± 0.01	0.42 ± 0.01	0.46 ± 0.01	0.50 ± 0.01	0.53 ± 0.01
	t- value	**NS**	**3.67***	**3.50***	**3.50***	**5.06****	**7.35****	**7.36****
Peroxide value (meq/kg of sample)	T_1	0.50 ± 0.10	0.90 ± 0.10	1.30 ± 0.10	1.80 ± 0.10	2.30 ± 0.10	2.80 ± 0.10	3.30 ± 0.10
	T_3	0.40 ± 0.10	0.70 ± 0.10	1.00 ± 0.15	1.20 ± 0.10	1.50 ± 0.10	1.80 ± 0.10	2.20 ± 0.10
	t- value	**NS**	**NS**	**2.53****	**7.35****	**9.80****	**12.25****	**13.472****

Table 8: Instrumental colour value (*L*, a*, b**) of Basella leaf powder incorporated *Khakhra* during ambient storage condition

	Treatments	Initial	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
L*	T_1	29.88 ± 0.01	29.40 ± 0.10	28.80 ± 0.10	28.40 ± 0.10	28.00 ± 0.10	27.50 ± 0.10	27.10 ± 0.10
	T_3	22.07 ± 0.01	21.80 ± 0.10	21.40 ± 0.10	21.10 ± 0.10	20.80 ± 0.10	20.50 ± 0.10	20.20 ± 0.10
	t- value	**956.53****	**93.08****	**90.63****	**89.41****	**88.18****	**85.73****	**84.51****
a*	T_1	7.26 ± 0.01	7.42 ± 0.01	7.44 ± 0.01	7.65 ± 0.02	7.94 ± 0.01	7.96 ± 0.01	7.98 ± 0.01
	T_3	4.46 ± 0.01	4.54 ± 0.01	5.00 ± 0.30	4.78 ± 0.01	5.02 ± 0.02	5.08 ± 0.01	5.17 ± 0.02
	t- value	**342.93****	**352.73****	**7.095****	**222.31****	**226.18****	**353.95****	**217.66****
b*	T_1	28.85 ± 0.01	28.60 ± 0.10	28.36 ± 0.01	28.10 ± 0.10	27.86 ± 0.01	27.61 ± 0.01	27.34 ± 0.10
	T_3	23.43 ± 0.01	23.20 ± 0.10	22.95 ± 0.01	22.70 ± 0.10	22.46 ± 0.01	22.30 ± 0.10	21.96 ± 0.10
	t- value	**663.81****	**66.14****	**662.59****	**66.14****	**661.36****	**91.52****	**658.91****

Table 9: Sensory evaluation (9-point hedonic scale) of Basella (*Basella alba*) leaf powder incorporated *Khakhra* during ambient storage condition

Products	Treatments	Initial	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Colour and appearance	T_1	8.50 ± 0.10	8.50 ± 0.10	8.50 ± 0.10	8.20 ± 0.20	7.90 ± 0.20	7.50 ± 0.10	7.10 ± 0.10
	T_3	8.00 ± 0.10	8.00 ± 0.10	7.90 ± 0.20	7.70 ± 0.10	7.50 ± 0.10	7.50 ± 0.10	7.40 ± 0.10
	t- value	**6.12****	**6.12****	**4.65****	**3.87****	**3.10***	**NS**	**3.67****
Taste	T_1	8.00 ± 0.10	7.79 ± 0.01	7.75 ± 0.10	7.50 ± 0.10	7.25 ± 0.02	7.25 ± 0.01	7.10 ± 0.10
	T_3	8.75 ± 0.01	8.79 ± 0.01	8.50 ± 0.01	8.25 ± 0.01	8.00 ± 0.10	7.75 ± 0.01	7.50 ± 0.10
	t- value	**12.93****	**122.47****	**12.93****	**12.93****	**12.74****	**61.24****	**4.90****
Flavour	T_1	8.00 ± 0.10	7.95 ± 0.01	7.92 ± 0.01	7.42 ± 0.01	7.17 ± 0.01	7.25 ± 0.01	6.92 ± 0.01
	T_3	8.75 ± 0.01	8.72 ± 0.01	8.67 ± 0.01	8.17 ± 0.01	7.92 ± 0.01	8.00 ± 0.10	7.67 ± 0.01
	t- value	**12.93****	**94.31****	**91.86****	**91.86****	**91.86****	**12.93****	**91.86****
Texture	T_1	8.00 ± 0.10	8.00 ± 0.10	7.95 ± 0.20	7.92 ± 0.01	7.83 ± 0.01	7.5 ± 0.10	7.42 ± 0.01
	T_3	8.50 ± 0.10	8.45 ± 0.01	8.42 ± 0.01	8.27 ± 0.01	8.25 ± 0.01	8.17 ± 0.01	8.12 ± 0.01
	t- value	**6.12****	**7.76****	**4.70****	**42.87****	**51.44****	**11.55****	**85.73****
Overall acceptability	T_1	8.00 ± 0.10	7.92 ± 0.01	7.67 ± 0.01	7.50 ± 0.01	7.42 ± 0.01	7.17 ± 0.01	7.00 ± 0.10
	T_3	8.75 ± 0.01	8.67 ± 0.01	8.50 ± 0.01	8.42 ± 0.01	8.17 ± 0.01	8.00 ± 0.10	7.92 ± 0.01
	t- value	**12.93****	**91.86****	**14.31****	**30.62****	**30.62****	**14.31****	**15.86****

Table10: Microbial population of Basella (*Basella alba*) leaf powder incorporated *Khakhra* during ambient storage condition

Treatments	Bacterial count (10^3cfu/g)		Molds (10^2cfu/g)	
	Initial	90 DAS	Initial	90 DAS
T_1(60 gWF)	ND	0.88 ± 0.01	ND	1.09 ± 0.07
T_3(52.5 gWF+ 7.5 g BLP)	ND	0.74 ± 0.01	ND	0.80 ± 0.10
t- value		**15.92****		**4.66****

Conclusion

From the study, it can be concluded that incorporating dehydrated *Basella alba* powder significantly enhances the nutritional value of the developed product *khakhra* with enhanced by β-carotene content of6.85 folds compared to control samples. The sensorily best-accepted Basella-enriched *khakhra* with the formulation of 52.5 g wheat flour, 20 g bengal gram flour, 20 g bajra flour and 7.5 g Basella powder, exhibited excellent physico- chemical properties, high levels of bioactive compounds (total phenols and antioxidant activity) than the control *khakhra* and remained microbiologically safe and organoleptically acceptable for up to three months in aluminium pouches under ambient condition.

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References

Abbey, B.W. and Ibeh, G.O. (1988). Functional properties of raw and heat processed cowpea (*Vigna unguiculata*, Walp) flour. *J. Food Sci*., **53(6)**, 1775-1777.

Ajila, C.M., Leelavathi, K. and Prasada, R.U.J.S. (2008). Improvement of dietary fiber content and antioxidant properties in soft dough biscuit with the incorporation of mango peel powder. *J. Cereal Sci*., **48**, 319-326.

Akshata, A.V. (20180. Development of value-added products from betel leaves *(Piper Betel* L.), *M.Sc. (Agric.) Thesis*, Univ. Agric. Sci., GKVK, Bengaluru (India).

Anonymous (1980). *Official Methods of Analysis*, 13th edition. Association of Official Agricultural Chemists, Washington, D. C. 2004.

Begum, S., Das, P.C. and Karmoker, P. (2018). Processing of mixed fruit juice from mango, orange and pineapple. *Fundam. App. Agric.*, **3(2)**, 440-445.

BeMiller (2017). Carbohydrate analysis, *Food Anal.,* 333-360.

Benzie, I.F. and Szeto, Y.T. (1999). Total antioxidant capacity of teas by the ferric reducing antioxidant power assay. *J. Agric. Food Chem*., **47(2)**, 633-636.

Bligh, E.G. and Dyer, W.J. (1959). Estimation of total lipids. *Can. J. Biochem. Physiol*., **37**, 911.

Chouhan, Y.K., Fransis, A., Sahu, D. and Thakur, R. (2019). Optimization of enzymatic concentration in tamarind pulp extraction. *Int. J. Conserv. Sci*., **7(5)**, 2953-2956.

Glassgen, W.E., Metzger, J.W., Heuer, S. and Strack, D. (1993). Beta-cyanins from fruits of *Basella rubra*. *Phytochem.*, **33(6)**, 1525-1527.

Hamsa, R., Bhuvaneshwari, G., Jagadeesh, S.L., Chandrashekhar, V.M., Basavaraj, N. and Natikar, N.A. (2021). Evaluation of hypoglycaemic activity of spine gourd powder (*Momordicadioica* Roxb.) formulated product (*Khakhra*) in STZ induced diabetic rats. *J. Appl. Hortic.,* **23(3)**, 334-337.

Jackson, M.L. (1973). *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd, Publications New Delhi.

Kajla, P., Shobhit, S. and Sharma, A. (2020). Preparation and quality evaluation of *khakhra* prepared from composite flour mix. *Ann. Biol.*, **36(3)**, 479-482.

Kamble, V. and Bhuvaneshwari, G. (2018). Processing and estimation of nutritional composition of drumstick (*Moringa oleifera*) leaf powder for human consumption. *J. Pharmacogn. Phytochem.,* **7 (3)**, 236-241.

Khalid, S., Aslam, M., Syed F., Imran, M., Saad, B. and Noreen, S. (2020). An insight to Vitamin A: A neglected vitamin. *EAS J. Nutr. Food Sci.*, **2**, 107-128.

Lindsay, W.L. and Norvell, W.A. (1978). Development of a DTAP soil test for iron, manganese, copper and zinc. *Soil Sci. Soc. American J*., **42(3)**, 421-428.

Maghu, T.K., Sharma, A., Younis, K. and Younis, K. (2017). Effect of drumstick leaves (*Moringa oleifera*) incorporation on quality of *khakhra*. *PBNPDA*., 129-144.

Ojure, M.A. and Quadri, J.A. (2012). Quality evaluation of noodles produced from unripe plantain flour using xanthan gum. *Int. J. Recent Res. Appl. Stud*., **13**, 740-752.

Panse, V.G. and Sukhatme, P.V. (1985). *Statistical Methods for Agricultural Research*. ICAR, New Delhi, **8**, 308-318.

Park, C.S. and Baik, B.K. (2004). Significance of hardness of wheat starch on processing and textural properties of cookies. *Cereal Chem*., **81(4)**, 521-526.

Punia, D. and Gupta, M. (2009) Sensory characteristics, nutrient composition and storage studies of value-added products for children. *Nutri. Food Sci.,* **39(5)**, 503-510.

Ranganna, S. (1986). *Handbook of Analysis and Quality Control for Fruit and Vegetable Products,* Second Ed., 1–30, Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

Ranganna, S. (2002). *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. Tata McGraw Hills Publishing Co. Ltd., New Delhi.

Reddy, V., Urooj, A. and Kumar, A. (2005). Evaluation of antioxidant activity of some plant extracts and their application in biscuits. *Food Chem.,* **90**, 317–32.

Shade, A., Jacques, M.A. and Barret, M. (2017). Ecological patterns of seed microbiome diversity, transmission and assembly. *Curr. Opin. Microbiol.*, **37**, 15-22.

Sharma, N. (2010). *Aloe vera* leaf powder (AVLP): Nutrient composition, development of ready to eat snacks and its clinical potential, *Ph D. (Home Sci.) Thesis*, Maharana Pratap Univ. Agri. Sci. Tech., Udaipur, Rajasthan, (India).

Shobhit and Sharma A. (2023). Development and quality evaluation of *masala khakhra* fortified with moringa leaves powder. *Annals Agri. Bio.Res.,* **28(1)**, 130-135.

Sowmya, M., Jeyarani, T., Jyotsna, R. and Indrani, D. (2009). Effect of replacement of fat with sesame oil and additives on rheological, microstructural, quality characteristics and fatty acid profile of cakes. *Food Hydrocoll.*, **23(7)**, 1827-1836.

Sriwattana, S., Laokuldilok, N. and Prinyawiwatku, W. (2008). Sensory optimization of broken rice-based snacks fortified with protein and fiber. *African J. Food Sci.*,**73(6)**, 333-338.

Sudha, M.L., Baskaran, V. and Leelavathi, K. (2007). Apple pomace as a source of dietary fiber and polyphenols and its effect on the rheological characteristics and cake making. *Food Chem.,* **104**, 686-692.

Vanaliya, S., Rao, P.S., Rao, S.K. and Sameja, K. (2012). Pharmacognostical study of *Basella alba* stem. *Int. J.Res. Pharm.*, **3(3)**,1093-1094.

Varsha, K. (2023). Studies on optimization and quality evaluation of value-added products from raw tamarind (*Tamarindus indica* L.) pods and leaves, *M. Sc. (Hort.) Thesis,* Univ. Hort. Sci., Bagalkot (India).